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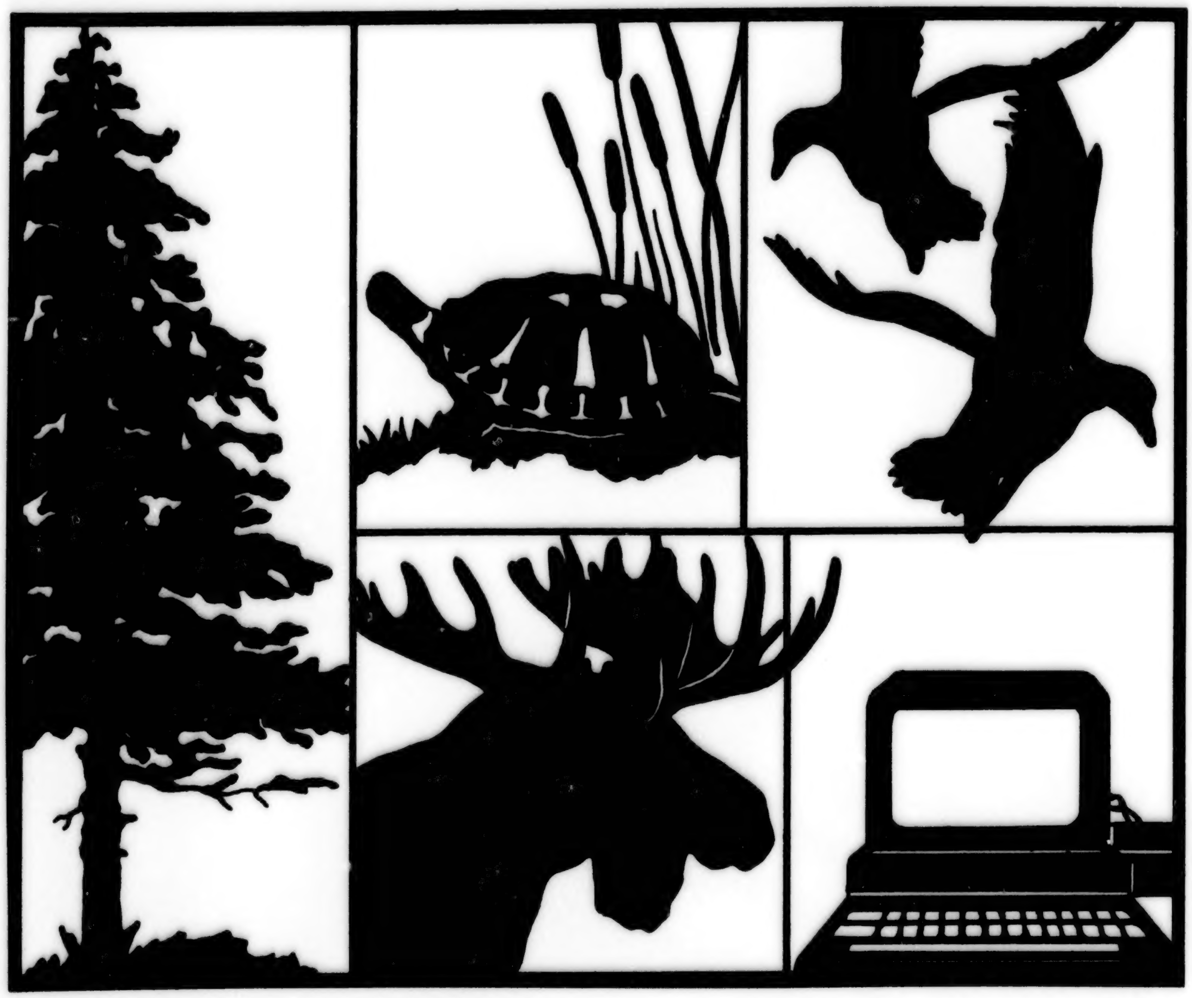
Guidelines for the Development of Community-level Habitat Evaluation Models



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Guidelines for the Development of Community-level Habitat Evaluation Models

By

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Guidelines for the Development of Community Level Habitat Evaluation Models

by

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Abstract. An increasing number of community-level models are being developed for assessment of impacts, mitigation of losses, or management of wildlife habitat. A review of these models indicates that a checklist of basic guidelines would assist biologists in improving model quality and usefulness. Guidelines are provided for the output definitions and testing, documentation of sources, statement of assumptions, definitions of variables, verification of performance, and levels of resolution. Examples from existing models are used to illustrate the strengths and weaknesses of different approaches.

Key words: Community, habitat, evaluation, models, wildlife.

Concern over the declining quality and quantity of natural communities is reflected in the U.S. Fish and Wildlife Service's (1991) planning document:

> The loss of biodiversity and decline in natural communities have accelerated dramatically due to over exploitation, pollution, habitat fragmentation, exotic species introduction and human-induced alteration of ecosystems.

This concern has been expressed in practical terms in the increasing development and application of community-level habitat evaluation methods during the last several years. An earlier review of concepts and approaches for the use of community models in wildlife impact assessment briefly summarized several models (Schroeder 1987).

The impetus for this report had two major sources. First, several years have passed since the publication of guidelines for the development of Habitat Suitability Index (HSI) models (U.S. Fish and Wildlife Service 1981) and publication of HSI models in the technical report series (Schamberger et al. 1982). Although most HSI models were developed for individual species, much of what was learned about modeling can be applied to community approaches as well. Second, the number of biologists developing and using community-level evaluation models has steadily increased. A review of many of these models indicates that a checklist of guidelines would be helpful in producing higher quality products. Examples from existing models are used throughout this report to illustrate adequate and inadequate methods for the development of community models.

Our intent in describing what we view as inadequate methods is to be constructive and offer insights into potential problems. The reviewed models represent the best efforts of model development and many hours of work by dedicated professionals. By definition, all models are simplifications of reality and cannot accurately describe all aspects of complex biological systems. However, many models can be improved by simply ensuring that certain steps are followed during their development.

A basic definition of a biotic community is "any assemblage of populations living within a prescribed area or physical habitat" (Odum 1971:140). The importance of the need for interactions between these population assemblages is emphasized by Whittaker (1975) and Ricklefs (1979). An entire biotic community consists of all living organisms in the defined area. Most community-level models focus on vertebrate populations. Furthermore, very few models assess population interactions or functions such as energy flow or nutrient cycling in a community. Therefore, we focus on models that estimate some attribute of vertebrate wildlife assemblages.

A community-level habitat model predicts the status or quality of a specific attribute of particular vertebrate wildlife assemblages based on habitat and spatial variables. The attribute may be any of several community features, such as species richness, guild richness, biomass, or trophic structure. An ideal community-level model estimates measures of productivity, but we did not encounter such models during our review.

In common practice, determination of community boundaries is somewhat arbitrary and often related to a vegetation type. For example, some community models evaluate the quality of wildlife habitat in bottomland hardwood forests, saline marshes, and riparian shrublands.

Community models are used when the goal is to obtain a larger view of the system than is possible with a single species approach. The following reasons were provided to indicate the intent of several recently developed community-level habitat evaluation methods:

- The need for a holistic approach to portray overall ecological conditions (Frye 1984).
- The desire to portray the needs of many species or species groups (U.S. Fish and Wildlife Service. 1989. Habitat suitability index models for riparian areas of the Sacramento river system. Sacramento Field Office, California. Unpublished report).
- The need to assess the overall suitability of a wetland for that group of wildlife species closely associated with wetlands (Ammann and Stone 1991).

Given the inherent difficulty in developing a model to meet these needs, community models must be developed by reasonable and consistent guidelines and the best available knowledge. This report provides basic guidelines for the development of community-level habitat evaluation models with existing information. This report does not provide guidance for conducting field studies of wildlife communities and does not describe mathematical or statistical procedures in modeling. The material is intended primarily for biologists who must evaluate the quality of wildlife communities for impact assessment, mitigation, or management.

Guidelines for Community-level Habitat Models

Clearly Defined, Testable Output

A community model must yield an output that relates to a specific attribute of the community, the meaning of which can be clearly described and communicated. The output should be related to a community attribute that is tangible and measurable to allow calibration and testing of the model. The lack of a clearly defined, testable output is a serious problem of many community models.

A good rule of thumb in evaluating the clarity of a model output is to ask: "How would this output be tested?" If the output is clearly related to a community attribute, it can be tested for accuracy. If the output is ambiguous, a logical, scientific test is impossible. Furthermore, a clearly defined output provides essential guidance for gathering data to develop the model and to construct model relations.

Most reviewed community models have outputs that imply relations to wildlife species richness. Many of these models, however, do not clearly define what aspect of species richness is intended to be measured. Richness can be measured for all vertebrate species or for particular groups of species (e.g., species sensitive to habitat fragmentation, native species, bird species). Measures of overall richness do not provide information about which species are present. Therefore, community model outputs related to richness should specify whether the measure is restricted to particular groups of species.

The following examples illustrate potential problems associated with defining model outputs.

Example 1. Several community level models were developed for the Sacramento River Bank Protection Project (U.S. Fish and Wildlife Service. 1989. Habitat suitability index models for riparian areas of the Sacramento river system. Sacramento

Field Office, California, unpublished report) to evaluate impacts and required mitigation. Separate models were developed for upland–herbaceous, scrub–shrub, riparian forest, and shaded riverine aquatic habitat types. The output of these models is on a 0 to 1 scale. However, the Habitat Suitability Index (HSI) value is not an exact measure of the habitat value for any single terrestrial wildlife species. Instead, the HSI indicates the overall, broad quality of the cover type for a broad array of the most important wildlife.

The phrases "overall, broad quality," "broad array," and "important wildlife" are ambiguous and need clarification. What is meant by overall quality? How many species does it take to have a broad array? Which wildlife species are deemed important and why? The model developers have not communicated the meaning of these terms to the users. A rigorous test of this model is therefore not possible.

Example 2. The Missouri Wetland Evaluation Technique (Missouri Department of Conservation and U.S. Soil Conservation Service. 1990. Missouri wetland evaluation technique. Unpublished report) is designed to evaluate the biological value of small wetlands. The output of this model ranges from 0.1 to 1.0. The meaning of the output is as follows:

> The guide evaluates the value of the wetland to fish and wildlife with wetlands capable of supporting a diversity of fish and wildlife species rating high.

This definition is less ambiguous than the definition in the previous example but still lacks sufficient clarity for a complete understanding. Diversity can be defined in different ways, for example, as the number of species in a given area (synonymous with species richness) or as a measure of both species richness and the equitability of relative importance among the species (e.g., diversity indices such as the Shannon–Wiener index [derived independently by Shannon and Wiener and sometimes mislabelled the Shannon–Weaver function, Krebs (1978)]). Without further clarification, the output of the Missouri Wetland Evaluation Technique cannot be completely understood or tested.

Example 3. The Wetland Value Assessment Methodology was developed to provide a uniform and quantitative habitat-based assessment for evaluating coastal wetlands in Louisiana (Coastal Wetland Planning, Protection, and Restoration Act Technical Committee. 1991. Wetland value assessment methodology and community models. U.S. Fish and Wildlife Service, Lafayette, Louisiana. Unpublished report). This method includes community-level models for fresh, brackish, and saline marshes and for baldcypress–tupelo swamps. The output of each model ranges from 0 to 1.0 and is defined below.

> The models have been developed for determining the suitability of Louisiana coastal wetlands in performing or providing a diverse array of functions and values including, but not limited to, providing resting, foraging, breeding, and nursery habitat to a diverse assemblage of fish and wildlife species; providing storm-surge protection, flood water storage, and water quality functions; and serving in nutrient import/export. The models attempt to define an optimum combination for all functions and values provided or performed by those systems.

This model output combines several very different factors into a single overall score. Because of this, the output cannot be interpreted for wetlands that rank less than optimum (<1.0 overall score). For example, does an overall score of 0.5 indicate that all of the factors described in the definition are present at the 0.5 level? Or could an overall 0.5 score indicate optimum conditions for some functions and unsuitable conditions for others? Model outputs that relate to two or more distinct attributes of the community should not be combined into one score. This type of output cannot be clearly understood or rigorously tested.

Example 4. An HSI model was developed to evaluate shelterbelt habitat in the northern Great Plains (Schroeder 1986). The output of the model ranges from 0 to 1.0 and is defined as follows:

> An output of 1.0 represents a shelterbelt with the maximum year-round number of vertebrate wildlife species (wildlife species richness) to be expected for an individual shelterbelt, and outputs approaching 0 represent successively lower values of species richness.

This output is defined in fairly clear terms and relates to one specific attribute of the community. The definition could be improved by describing when a species is considered to occupy a shelterbelt.

For example, is a species included in total species richness if it is migratory or uses the shelterbelt only occasionally for a song perch? Only after such a determination was made could the output be tested.

Model Tested with Empirical Data

Beyond having a clearly defined and testable output, a long-term goal for any community model should be a test of its output against observed conditions. Model testing consists of comparing model outputs with actual measurements of the community-level attribute. Testing hypotheses often provides insights into model performance that can be used to improve the model credibility and the reliability of a model.

The testing of models is difficult and time consuming. Ideally, a model should be tested over a long period, in a variety of geographic locations, and in habitats with the full range of conditions for which the model will be applied. In reality, tests are often limited in scope, and their results should be interpreted carefully. We are not aware of other published results of community models tests and therefore use our own work as an example here. It should be noted that shelterbelts represent a simple system and that bird species richness is a simple community measure. Tests of models with more complex community measures and in more complex systems are more difficult.

Example. The shelterbelt community model was tested with data from a 3-year study of 34 shelterbelts in eastern Kansas (Schroeder et al. 1992). A comparison of model predictions with actual breeding bird species richness indicated that the model performed well but could be improved. Data collection revealed several areas where measurement of model variables was difficult. For example, the original model required a measure of the number of shelterbelt rows. Because of the high degree of woody regeneration in older shelterbelts, this variable could not always be accurately measured. In addition, data analyses indicated revisions in the quantitative relations within individual variables would improve accuracy. The revised model was a strong predictor of breeding bird species richness in the 34 shelterbelts ($r^2 = 0.893$; $P < 0.001$).

Documentation of Sources of Information

Models generally contain many assumptions to support specific hypotheses. The strength of these hypotheses is directly related to the amount and quality of supporting data. Documentation of information sources that were used to develop a model is essential because users can judge the logic and credibility of the model, examine the supporting literature and data, and more easily revise the model for particular applications.

Adequate documentation includes the names and addresses of the developers and enough detail to determine the exact source of the information that was used to develop each part of the model. For example, if the model is based on professional judgment or unpublished data, this information should be clearly stated. For data from published sources, a minimum level of documentation is a citation without details. However, documentation with enough detail from the citation for determination of the reliability of the source is helpful.

Following are examples of documentation in some of the community models we reviewed.

Example 1. The Wetland Evaluation Technique (WET) contains a model to rate the ability of a wetland to support a diversity or abundance of wetland dependent birds (Adamus et al. 1987). In the palustrine portion of this model (page 129), five variables are listed to determine whether a wetland should receive a high rating. A partially permanently flooded or intermittently exposed palustrine wetland contributes to a high rating. No documentation is provided to allow a model user to determine why the variables were chosen or to evaluate the credibility of the source of information from which the model relations were derived.

Example 2. Greason et al. (1978), the authors of an Ontario wetland evaluation system state that wetlands with a diversity of aquatic and terrestrial habitats and a large number of plant species attract a larger number of wildlife species than more uniform wetlands (Environment Canada and Ontario Ministry of Natural Resources 1984). Greason et al. (1978) were editors of symposium proceedings of 56 articles and 674 pages. Because the documentation does not refer to a specific article, it is difficult to find the actual source and judge its reliability.

Example 3. Short (1984) developed a model to assess wildlife species richness in the Sonoran desert of west-central Arizona by evaluating either the number of potential guilds or the number of habitat layers. Information from 18 sources was used to develop the logic and provide the data for development of the hypotheses in the model. For example, the assumption that vertebrate species use specific layers of habitat as a basic strategy for partitioning resources is referenced with seven sources.

Clearly Stated Assumptions and Limitations

Community models are simplifications of reality and attempts to predict complex biological conditions by measuring key components of the system. Each model is built upon a series of assumptions and each model has limitations. Assumptions are necessary because knowledge of the structure and function of wildlife communities is incomplete; models must be practical and useable, and information must often be extrapolated to new circumstances.

During the development of a community model, the builder is most aware of the necessary assumptions. A thorough discussion of assumptions demonstrates this awareness and communicates these assumptions to others. Clearly stated assumptions provide a basis for testing specific components rather than just the final output of the model.

A knowledge of the limitations of the model is also helpful to users. For example, a model developed with data from a specific geographic area is probably of limited value outside of this area. A model developed to analyze one particular community attribute has limitations when applied beyond this scope. The application of some community models is limited by the type of data required to apply the model such as detailed spatial measurements. This information must be available to users to ensure that the model is applied within appropriate limits. The following are statements about assumptions and limitations of community models.

Example 1. The Wetland Value Assessment Methodology contains a model for evaluating baldcypress--tupelo swamps in Louisiana (Coastal Wetland Planning, Protection, and Restoration Act Technical Committee 1991. Wetland value assessment methodology and community models. U.S. Fish and Wildlife Service, Lafayette, Louisiana. Unpublished report). A variable for water regime describes four categories of water permanence and provides a partial description of the assumptions used to develop model relations. The optimum condition is assumed to be seasonal flooding that in turn is assumed to provide increased vertical structure complexity (because of growth of other plants on the swamp floor) and increased recruitment of dominant overstory trees. The further unstated assumption is that these vegetation conditions provide optimum wildlife richness.

The water regime variable states that permanent flooding is assumed to be the least desirable condition. But a reason for this assumption is not provided. Is permanent flooding assumed to be poor because of a lack of vegetative structure? Does permanent flooding negatively affect overstory conditions? The user is left to infer the logic behind the assumption that permanent flooding is the least desirable condition.

Example 2. The Missouri Wetland Evaluation Technique (Missouri Department of Conservation and U.S. Soil Conservation Service. 1990. Missouri wetland evaluation technique. Unpublished report) contains a variable to measure the number of consecutive days that surface water is present in a wetland. The assumption is that the longer water is present, the greater is the value of the wetland for species requiring water for reproduction and winter habitat. The assumption clarifies the logic behind the variable but could be improved by noting which species are assumed to benefit and by providing a source for the information.

Example 3. The Method for the Comparative Evaluation of Nontidal Wetlands in New Hampshire (Ammann and Stone 1991) provides several models for evaluating various wetland functions, including ecological integrity and wildlife habitat. The introductory material provides a thorough description of the limitations of the method. Clear guidance is provided on appropriate and inappropriate applications. It is noted that the method is designed for general comparisons of wetlands and not for detailed impact analysis or other studies that require detailed information about individual wetlands.

Clearly Defined Variables

Model variables must be clearly defined to be understood and measured correctly. Frequently, the model builder has a clear understanding of what is to be measured but does not communicate it to model users. Terms such as "dense cover," "good plant diversity," or "primarily" must be defined and, if possible, quantified.

Clearly defined model variables improve the consistency of results between different users. An ideal model does not introduce variation because of poorly worded model variables. The following examples illustrate various degrees of clarity in model variables.

Example 1. The Missouri Wetland Evaluation Technique (Missouri Department of Conservation and Soil Conservation Service. 1990. Missouri wetland evaluation technique. Unpublished report) contains a variable for measuring concealment cover. Users are instructed to estimate the percent of the wetland covered by dense woody cover or dense herbaceous cover that remains erect over winter. No specific meaning is provided for the term "dense." Thus, users must either subjectively evaluate the meaning of "dense" or arbitrarily assign a quantitative rating to the term. A subjective assessment introduces tremendous variation because of various interpretations and user bias. Arbitrary assignment of a quantitative rating reduces variation but provides no assurance that the chosen value reflects the intentions of the model developer.

Example 2. Golet (1976) developed a model for evaluating the production and diversity of wildlife in wetlands of the northeastern United States. The model contains a variable for measuring the relative proportion and interspersion of vegetative cover and open water. The terms "cover" and "open water" are defined and a complete and inclusive description of the eight possible configurations is provided. In addition, an illustration portrays examples of each of the eight configurations. This degree of clarity in defining a model variable leaves very little need for interpretation.

The definitions of variables should be checked for clarity by individuals not involved in the development of the model. The application of the model in the field is highly recommended prior to its distribution or use. Field applications quickly reveal inconsistencies, poor definitions, or variables needing additional guidance for their application.

Adequate Verification of Model Performance

The performance of community models should be thoroughly analyzed with sample data at the time the model is developed and by users prior to applying the model. The model should be applied with sample data representing the extreme conditions expected to be encountered. The first step is to input raw data from several hypothetical situations and to analyze the outputs. Based on the information and data with which the model algorithms were constructed, the model builder or user must decide whether the outputs are reasonable. Verification of the performance of the model should consider the sensitivity of the output to changes in values of key variables.

These types of sensitivity analyses should not be confused with empirical tests. Analysis of the performance of a model with sample input values does not provide information on the relation of the output measure to the modeled community attribute. The purpose of the verification is to determine if for a hypothetical situation the model is operating in a reasonable manner.

Example 1. The output of the Missouri Wetland Evaluation Technique (Missouri Department of Conservation and U.S. Soil Conservation Service. 1990. Missouri wetland evaluation technique. Unpublished report) is related to fish and wildlife diversity. The model requires measurement of eight variables for obtaining a final score that ranges from 0.1 to 1.0 and is calculated as the simple average of the eight variable scores. The performance of the model was analyzed with hypothetical data sets. Maximum values were assigned to all variables except size of wetland. Wetlands ≥2 ha received the maximum score of 1.0, and wetlands ≤0.2 ha received a score of approximately 0.8. The implication is that very small wetlands have 80% of the wildlife diversity of very large wetlands, if all other variables are set as equal. Based on species-area relationships from other wetland studies (e.g., Graber and Graber 1976), it is not reasonable to expect such high levels of diversity in such small wetlands. Nor is it reasonable to assign a maximum value to any wetland ≥2 ha because wildlife diversity continues to increase with wetland size.

Example 2. The Wetland Value Assessment Methodology contains seven variables for determining the value of fresh marshes (Coastal Wetland Planning, Protection, and Restoration Act Technical Committee 1991. Wetland value assessment methodology and community models. U.S. Fish and Wildlife Service, Lafayette, Louisiana. Unpublished report). The final output ranges from 0 to 1.0 and is determined by a weighted geometric mean of indices from the seven model variables. An analysis of the performance of the model with sample data sets indicated that model outputs were insensitive to changes in several variables. For example, wetlands with very low ratings for edge and interspersion (0.2 index) scored 0.85 overall if other variables were at their maximum values. Whether this response mimics what was intended by the model builder is not clear.

In general, outputs determined from an arithmetic or geometric mean of four or more variables tend to dampen the significance of any one variable. Although this may be reasonable and mimic the intended condition, such mathematical relations should be used with caution. Complete and thorough analysis of a full range of sample data allows both model builders and users to verify the performance of such models.

Multiple Levels of Resolution

The available time for the application of a community level model varies. For major projects, biologists may have months to analyze effects of a proposed project or management plan. Frequently, however, constraints allow only a few days for evaluations. The most useful community level models, therefore, provide various levels of resolution for either simplified or detailed applications.

Detailed applications of community models require significant amounts of field work, probably including extensive vegetation sampling. The least detailed applications are accomplished from an office setting and use existing information. An ideal model provides guidance for the application at several levels of detail.

As computer-generated map coverage and related expertise become more widely available, they will simplify the application of community models. Remotely sensed data are ideal for measurement of many spatial and landscape variables, and such data often provide significant detail about plant associations and vegetation structure. If community models were linked to Geographic Information System (GIS) software, it would be feasible to conduct complex analyses of large areas in a short time.

The level of resolution of a model is not necessarily synonymous with the accuracy of the model. Models with a few easily obtained variables may be comparable in accuracy to models with many detailed variables.

Example. The bottomland hardwood model (which my coauthors and I are developing) provides recommendations for various levels of application. A complete application of the model requires measurement of eight habitat variables and five tract level variables. The habitat variables (e.g., tree diameter) require a site visit and field measurements, whereas the tract variables (e.g., isolation from adjacent tracts) can be obtained from remotely sensed data. Guidance is provided to allow users to concentrate their analysis on the tract level variables and either estimate or eliminate measurements of the site-specific habitat variables. The single most important determinant of species richness is tract size, and a measure of that variable alone may be useful for general applications. Thus, this model can be applied at several levels of resolution, depending on user needs.

Summary and Checklist

The guidelines in this paper are intended to improve the quality of community models for impact assessment and habitat management and address several major topics including output definitions, documentation of information sources, and testing of model performance.

Biologists who develop, review, or use wildlife community models are encouraged to follow these guidelines and to seek additional information on development and use of models (Bunnell 1989; Starfield and Bleloch 1986; U.S. Fish and Wildlife Service 1981). The following checklist facilitates a quick check of the status of a specific community model.

Checklist of Desirable Features

1. Clearly defined, testable output:
    - output is clearly defined
    - output can be tested against a specific community attribute
2. Model tested with empirical data:
    - some portions of the model have been tested
    - there are opportunities to test the model
3. Documentation of sources of information:
    - sources of information for development of the model hypotheses are clearly identified
    - citations are provided for published sources
    - sources are provided to check unpublished data
4. Clearly stated assumptions and limitations:
    - the model adequately describes assumptions used to develop hypotheses and model relations
    - limitations of the model are presented
5. Clearly defined variables:
    - a definition is provided for each variable

- variable definitions are unambiguous
- measurements of variables result in repeatable data

6. Adequate verification of model performance:
   - sample data sets are provided
   - the model was applied in a field setting prior to completion
   - the model provides reasonable outputs for the intended area of application
7. Multiple levels of resolution:
   - the model provides more than one level of resolution
   - the levels of resolution are meaningful for the intended applications and data availability

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U.S. DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fishes and wildlife, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and attempts to assure that their development is in the best interests of all our people. The Department also has a major responsibility for Native American reservation communities and for people who live in island territories under U. S. administration.

END

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